RESEARCH ON FOREST SOILS AND TREE NUTRITION

By H. G. MILLER and B. L. WILLIAMS

Macaulay Institute for Soil Research, Aberdeen

Work continues to be concentrated on various aspects of nitrogen nutrition. A new experiment has been laid out in pole-stage Scots pine growing on sand dunes to compare the effect of various forms of nitrogen fertilisers, combined factorially with applications of phosphorus and lime, on both tree growth and the immobolisation of nitrogen in the humus layer.

Tree Nutrition

Investigations described previously (*Reports* for 1965 to 1968) into the effect of nitrogen fertiliser on both tree growth and the distribution and movement of nutrients in a pole-stage crop (standing volume of 190 m^3 per ha) of Corsican pine at Culbin Forest, Moray, have now been largely completed. This crop was intensively sampled in February 1964, following which various rates of ammonium sulphate were applied over three years. Each treatment was subsequently resampled in February 1967. During the interval between samplings regular assessments were made of the weight of litter dropped by the trees and of the release of nutrients from the crop both in litter and by recretion (crown leaching) into rainwater.

By 1967 the weight of the tree crop in the different treatments ranged from 150,000 to 180,000 kg per ha, of which the stems accounted for about 60 per cent and the roots for 20 per cent. (The values given in previous *Reports* differ slightly from these owing to an error that was incurred in earlier calculations of the weight of lateral roots). The proportion of the crop weight represented by foliage, however, increased with treatment, rising from 5 per cent in the untreated control plots to 8 per cent in the two heaviest treatments. As a result of this increase in weight of photosynthetic tissue there were marked differences in tree growth between treatments, as can be seen from Table 29.

In Table 29 the values for net primary production represent the increased weight of the tree crop, including root systems, between February 1964 and February 1967 plus the weight of litter-fall over this period. However, no allowance has been made for root death and wastage.

The parameters of basal area, height and timber volume show markedly differing patterns of response to the fertiliser treatments, although the response in terms of volume fairly closely parallels the pattern of change in net primary production. In fact, stem tissues account for relatively little of the total net primary production, as low as 14 per cent in the control trees as against 42 per cent directed to foliage, including needle litter. In treatment N_3, on the other hand, not only was the total net primary production more than doubled but the proportion directed to stem formation increased to 30 per cent, with the foliage and needle litter now accounting for only 35 per cent.

The fertiliser applications resulted in a marked rise in the weight of nitrogen in the tree crop, from 195 kg per ha in the control plots to 680 kg per ha in

TABLE 29

EFFECT OF REPEATED APPLICATIONS OF AMMONIUM SULPHATE ON NEEDLE NITROGEN CONCENTRATION AND ON TREE GROWTH

Treatment	Rate of application kg N per ha per annum	Total application 1964–66 kg N per ha	% N in top-whorl foliage at Oct. 1966	Growth; 1964–66 inclusive			
				Basal area m^2 per ha	Top height (100 s.p. ha) m	Volume m^3 per ha	Net primary production Mg (10^6g) per ha
N_0	0	0	0·91	2·80	0·28	18·6	23·1
N_1	84	252	1·57	4·48	0·56	34·5	41·7
N_2	168	504	2·07	5·11	0·73	40·3	44·5
N_3	336	1007	2·26	5·43	0·58	39·8	46·7
N_4	504	1510	2·63	5·79	0·32	36·7	43·1
Standard error			0·13	0·35	0·08	2·9	
Linear trend			***	**	n.s.	*	
Quadratic trend			*	n.s.	**	**	

Notes: n.s. = not significant. Significance at the 5%, 1% and 0·1% levels denoted by one, two and three asterisks respectively.

treatment N_4. Increases with treatment were also recorded for the weights of phosphorus, potassium, magnesium and sodium, whereas the weight of calcium tended to show a slight decrease.

The increased weight of nutrients within the tree crop represents only a proportion of the total uptake, the rest being released both in litter-fall and by recretion into rainwater. Recretion was found to be a fairly minor process in the redistribution of nitrogen and phosphorus, indeed in the lower treatments there was a net absorption of nitrogen from rainwater by the tree foliage. On the other hand, recretion results in high losses of potassium, calcium, magnesium and sodium which, except for calcium, exceeded the quantities released in litter-fall.

Over the three-year period of study mean annual uptake of nitrogen in the control plots was only 16 kg per ha as against a value of 143 kg per ha in treatment N_3, the treatment in which the highest net primary production was recorded. Mean annual uptakes of other elements in these two treatments were, respectively, 4 and 9 kg phosphorus, 19 and 57 kg potassium, 39 and 37 kg calcium, 10 and 11 kg magnesium and 43 and 33 kg sodium. The proportion of the total uptake that was released by the trees over this period tended to decrease with increasing growth rate. For example, in the control plots the quantity of nitrogen released was equivalent to 68 per cent of the weight of this element taken up by the trees, whereas in treatment N_3 it was equivalent to only 13 per cent of the uptake.

Application of ammonium sulphate was found to result in increased concentrations of nitrogen not only in the tree crop but also in the waste organic matter on the forest floor. However, no increases in concentration were detectable in the mineral soil, which in this forest consists of over 99 per cent coarse and fine sand and has an extremely low organic matter content. In treatment N_1 the amount of additional nitrogen found in the ecosystem in 1967 was comparable to the amount known to have been supplied, but at the heavier treatment rates appreciable loss of fertiliser nitrogen had occurred, the recovery amounting to only 75, 55 and 45 per cent of the amount applied in treatments N_2, N_3 and N_4 respectively. The greater part of this nitrogen was located in the tree crop, which accounted for 55 to 70 per cent of the fertiliser nitrogen retained in the ecosystem, the proportion increasing with increasing rate of application.

Thus in all treatments the tree crop acted as a more important store of fertiliser nitrogen than did the litter and humus layers, and this may in part account for the relatively long-lasting effect of nitrogen fertiliser on the growth of coniferous trees (*Report* for 1968). Two-dimensional paper chromatography suggests that appreciable storage occurs as free amino-acids, there being marked differences in the concentration of these between untreated and fertilised trees. Of the amino-acids identified in needle extracts, α-alanine, γ-aminobutyric acid and arginine were present in the greatest amounts, in general agreement with the results obtained by Muir *et al.* (1964) with Scots pine. However, arginine, in particular, was present in very much greater amounts than suggested by these authors and in view of the marked seasonal variation that has been found in the concentration of arginine in fruit trees this matter requires further investigation. Newly fallen litter was also found to contain appreciable amounts of free amino-acids despite the marked reduction in the concentration of nitrogen that occurs in needles prior to abscission.

Studies on Peat

In co-operation with the Peat Section (Department of Pedology) of the Macaulay Institute, and the Research Branch of the Forestry Commission, a study was undertaken to ascertain whether the subdivision of a blanket bog into site types on the basis of topography and ground vegetation, using large-scale aerial photographs, could be related to the nutrient content of the peat. Such a classification carried out on an area of blanket bog in Strath Tirry (Sutherland) produced seven site types and a series of profiles were sampled on a volume basis, in each of these. The nutrient content of the peat (expressed in kg per ha) was found, with certain exceptions, to be fairly closely related to site type. Analysis of the results suggests the presence of two distinct trends, these apparently being related to erosion on the one hand and to "flushing" with mineral-rich ground water on the other. Both processes result in an increased weight of dry peat material per unit volume of fresh peat, and this was found to be the predominant factor controlling nutrient content of the peat, both in the immediate surface horizons and to a depth of 0·5 metres. However, flushing is also associated with high concentrations of nitrogen, phosphorus and potassium, whereas erosion is associated with high concentrations of calcium and magnesium.

Cation-exchange capacity of the fresh peat tended to increase with increased decomposition (humification) of the peat, and was therefore higher in the drier eroded types. However, in these the concentration of exchangeable bases is low and the degree of base saturation is correspondingly low. In the flushed types, on the other hand, although the cation-exchange capacity is low due to the small weight of solid matter per unit volume of fresh peat (high moisture content), the concentration of exchangeable bases is relative higher, increasing with increasing degree of flushing, and so the degree of base saturation is greater than in the eroded types.

The different site types could be readily related to variations in the relative proportions of the main components of the vegetation. However, although the site types showed appreciable differences, the significance of these with respect to tree growth has still to be determined, particularly as management techniques, such as drainage and cultivation, may well have differing effects on the various site types.

Summary

Treatment of Corsican pine growing on sand dunes with ammonium sulphate considerably increased tree growth, but whereas basal area increment continued to increase over the full range of treatments applied, height increment, volume increment and net primary production were depressed at the highest rate of treatment. The treatments resulted in marked increases in uptake by the trees, not only of nitrogen but also of phosphorus and potassium. By the end of the experiment a greater amount of the fertiliser nitrogen was located in the tree crop than in the litter and humus layers, and this increased nitrogen content was accompanied by an increase in the free amino-acid content of the tree foliage. A comparison has been made of the nutrient content of peat from a variety of site types delineated on an area of blanket bog according to features of topography and ground vegetation.

REFERENCE

MUIR, J. W., MORRISON, I. R., BOWN, C. J., and LOGAN, J. (1964). The mobilisation of iron by aqueous extracts of plants. I. Composition of the amino-acid and organic-acid fractions of an aqueous extract of pine needles. *J. Soil Sci.* **15**, 220–225.